Forward Kinematics

 $\boxed{f} \xrightarrow{\text{extraction}} H_{EE} = \begin{bmatrix} R & d \\ 0 & 1 \end{bmatrix}$

$h_{ij} \to$ function of $f_i(q_k)$ $k = 1 \dots n$

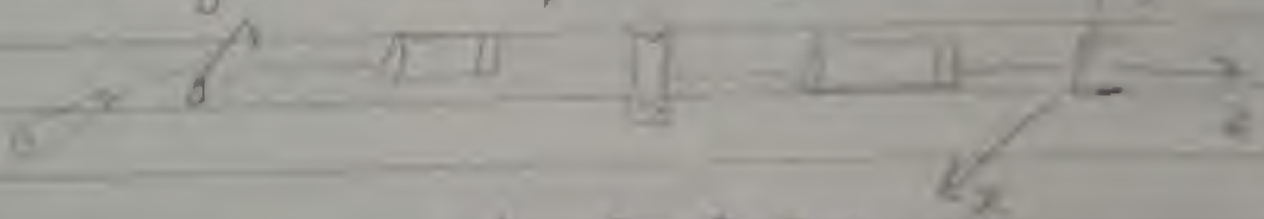
Inverse Kinematics & multiple solutions $q_k = g_k(\text{Pose})$

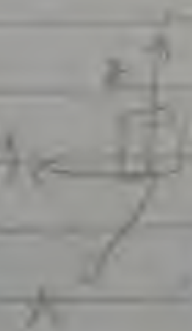
given desired pose

Pose $\boxed{\;?\;}$ → q_k given H_{EE} desired

End effector

model from solving 12 nonlinear eqns $h_{ij} \to$ certain value





$$H_{EE} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -12 \\ - & -1 & 0 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$f_1(q_k) = 1$

$f_2(q_k) = 0$

[illegible] $f_2 + f(q_k) = -12$

12 non linear equations

حسب عدد DOF ← [illegible]

1- Closed form

[illegible] Dependent [illegible] — [illegible]

$q_r \quad {}^{1}J_n(P, w)$

1. given form — [illegible]

2. [illegible] q [illegible]

$q^?$ [illegible] q [illegible]

Analytical method
[illegible]

Geometric
[illegible]
- Simple kinematic chain
- Robot Geometry

2- Numerical method

بالـ Forward K نقدر نستنتج متغير q عن طريق iteration
يستنتج حلول تقريبية

3- Artificial intellegence

Pose → N N → q

ANFIS [illegible]

Kinematic Decoupling: Geometric approach → [illegible]

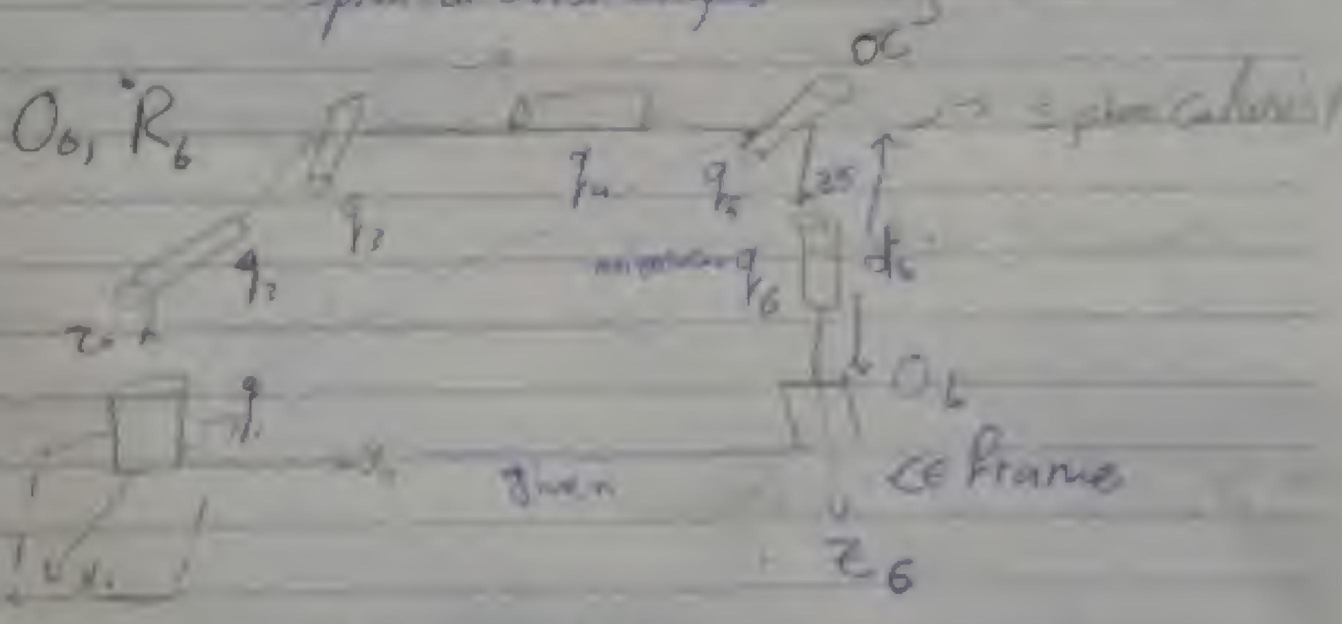
Robot

6. Dof manipulator
spherical wrist] given

wrist center = $f(q_1, q_2, q_3)$

orientation = $f(q_4, q_5, q_6)$
spherical wrist angles

given O_6, ${}^0R_6$



$$ {}^0O_6 = {}^0O_c + {}^0R_6\, d_6 \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} $$

$$ {}^0O_c = {}^0O_6 - d_6\, {}^0R_6 \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \longrightarrow (1) $$

O_{x_c}, y_c, z_c

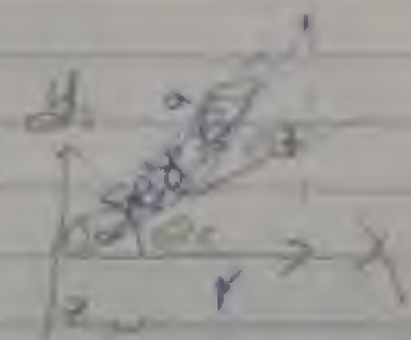
DATE :

SUBJECT :

$\theta_1 \longrightarrow$ هي الزاوية بين اسقاط الـ manipulator

ع المستوى الأفقي

$\theta_2 \longrightarrow$



$\tan\theta_1 = \frac{y_c}{x_c}$

$\theta_1 = \tan^{-1}\left(\frac{y_c}{x_c}\right) \longrightarrow (2)$

$= \mathrm{aTan2}(y_c, x_c) \longrightarrow$ matlab

بتراعي الربع وبتراعي الاشارات , بالتغير الدائري

$r = \sqrt{x_c^2 + y_c^2}$

$a^2 = r^2 + (z_c - d_1)^2$

$a^2 = x_c^2 + y_c^2 + (z_c - d_1)^2$

$\cos \gamma = \frac{a^2 + b^2 - c^2}{2ab}$

$c^2 = a^2 + b^2 - 2ab\cos \gamma$

$\cos \gamma = \frac{l_2^2 + l_3^2 - a^2}{2 l_2 l_3}$ → a^2

cosines law
$x_c^2 + y_c^2 + (z_c - d_1)^2$

$\theta_3 = 180 - \gamma$

$\cos \theta_3 = \frac{l_2^2 + l_3^2 + x_c^2 + y_c^2 + (z_c - d_1)^2}{2 l_2 l_3}$

$b = l_3 \cos \theta_3$ $\beta = \cos^{-1}\left(\frac{l_2 + l_3 \cos \theta_3}{\sqrt{x_c^2 + y_c^2 + (z_c - d_1)^2}}\right)$

DATE: ______ SUBJECT: ______

$$\theta_2 = \tan^{-1}\frac{z_c - d_1}{\sqrt{x_c^2 + y_c^2}} - \beta$$

α

$${}^0R_6 = {}^0R_3\,{}^3R_6 \qquad {}^3R_6 = ({}^0R_3)^{-1}\,{}^0R_6$$

$\theta_4, \theta_5, \theta_6$
using Euler parametrization.

substitute by $\theta_1, \theta_2, 3$